

Observations from Long-Term Performance Monitoring of the TOPEX Radar Altimeter

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From the August 1992 launch to the present, we have conducted performance analysis and engineering assessment for the TOPEX radar altimeter. We continually update entire-mission databases containing: i) on-board engineering parameters such as temperatures, voltages, and currents; ii) internal calibration mode indications of bias changes in range (Figure 1) and power estimates; and iii) global over-ocean averages of geophysical quantities including the ocean surface radar backscattering cross-section, σ_0 (Figures 2 and 3) and the significant waveheight, SWH (Figure 4).

For some time, we have seen an apparent increase in the TOPEX cycle-average SWH (Figure 4), amounting now to an increase of about 10% from the earlier mission value of about 2.8 m. Recently several investigators have reported that the TOPEX SWH is increasing relative to ERS-2 and to ocean buoy measurements. Detailed examination of early-mission TOPEX waveforms and recent waveforms show distinct change in the waveforms' leading edge, as seen in Figures 5 and 6. We examined the past six years of waveform data from an internal calibration mode (Cal 1) which samples the altimeter's point target response (PTR), and found that the PTR sidelobes are apparently greater now than at the start of the mission.

On 08 September 1998, a special command sequence operated the TOPEX altimeter in a special test mode (Cal Sweep) giving a more detailed view of the PTR than is obtained from the normal Cal 1. The September 1998 Cal Sweep data were compared with similar data from a 1991 pre-flight Cal Sweep (Figure 7). A time-dependent (or cycle-dependent) model PTR has been produced from the 1991 and 1998 Cal Sweep data, and by using waveforms from the normal Cal 1 to provide details of the time-evolution of the PTR (Figure 8).

Recent TOPEX simulation studies using this model cycle-dependent PTR can account for most of the apparent increase in the TOPEX SWH estimate (Figure 9). That is, the SWH increase is not real, but is the result of the systematic PTR change within the altimeter. Our simulations indicate the possibility of several centimeter changes in TOPEX range estimates as a result solely of the PTR changes seen to date (Figure 10). However, there will be an additional change in TOPEX ranges because the electromagnetic bias (EM bias) correction is a function of the SWH (Figure 11); an erroneously large SWH estimate will produce too large an EM bias correction. The resulting net error is the sum of the PTR change effect that needs to be applied and the error in the EM bias correction that was applied (Figure 12). We are now developing approximate recipes for correcting the TOPEX SWH values (Figure 13) and the range values (Figure 14), and this information will be made available on our web site (<http://topex.wff.nasa.gov/>).

We emphasize that any radar altimeter is a complex system requiring continuing calibration and monitoring throughout its entire lifetime.

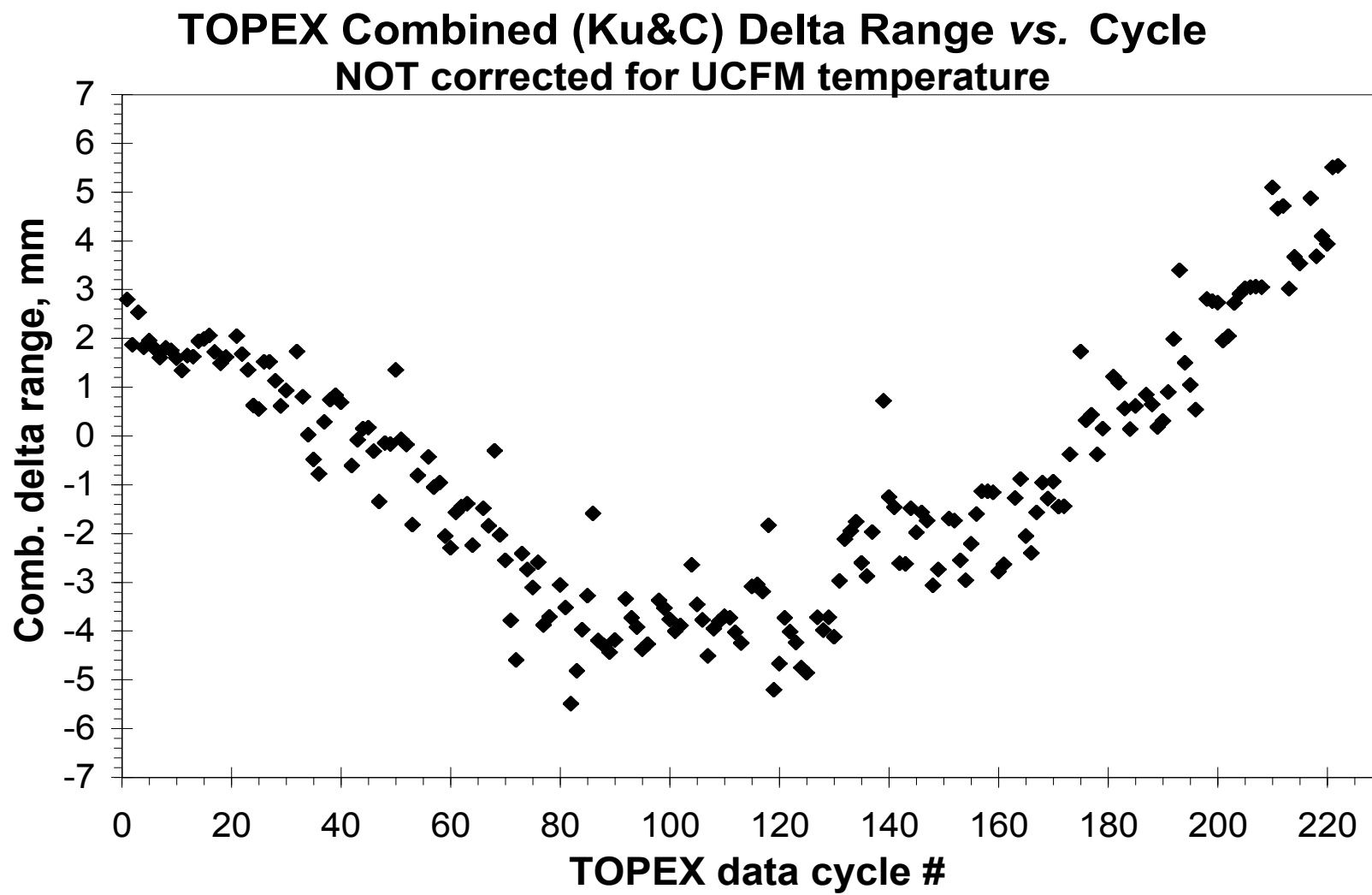


Figure 1

TOPEX Ku-Band Cycle-Avg Cal-1 and Cal-2 Delta AGC and Sigma0 (Cal Table Corrections Removed)

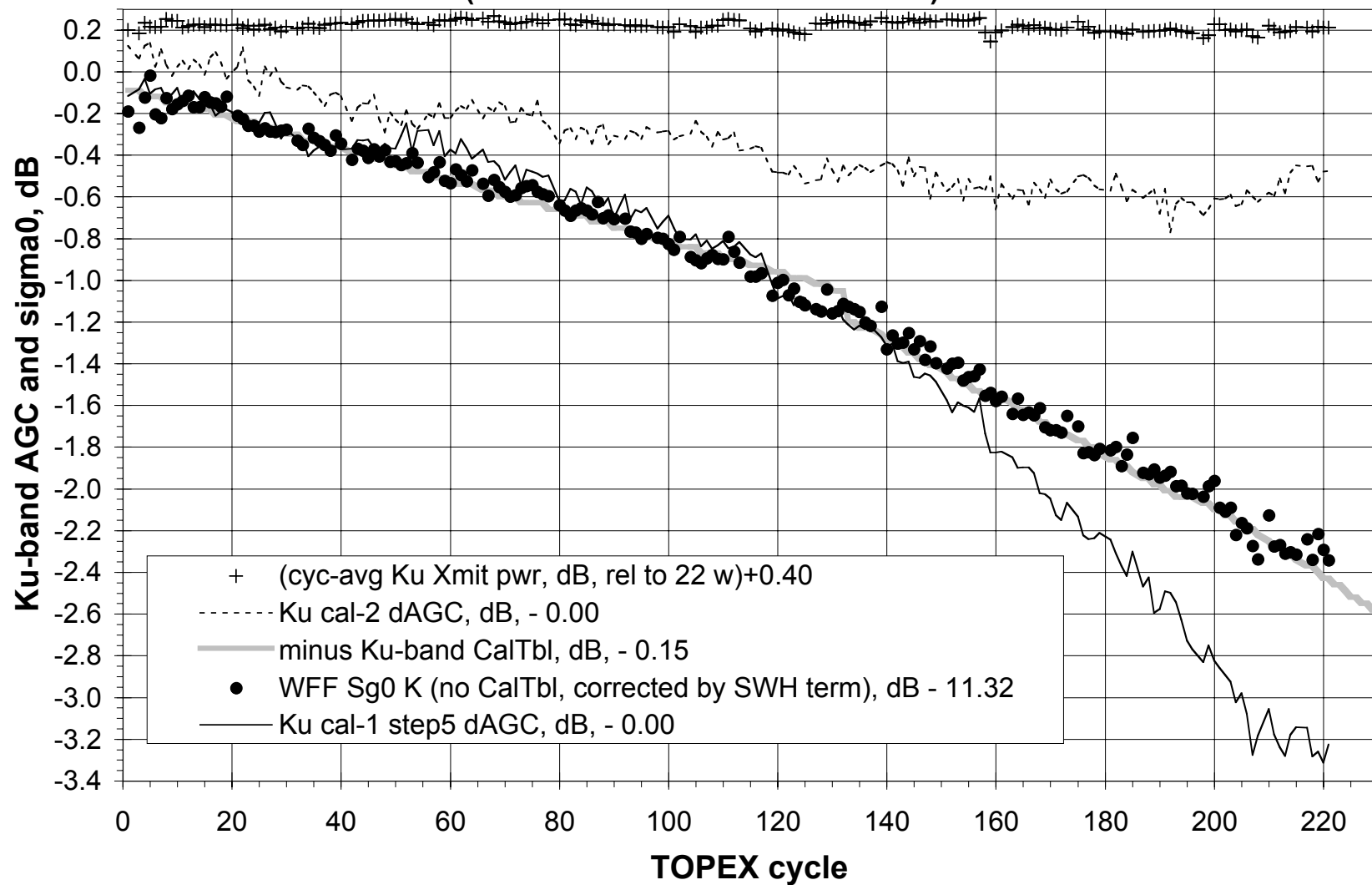


Figure 2

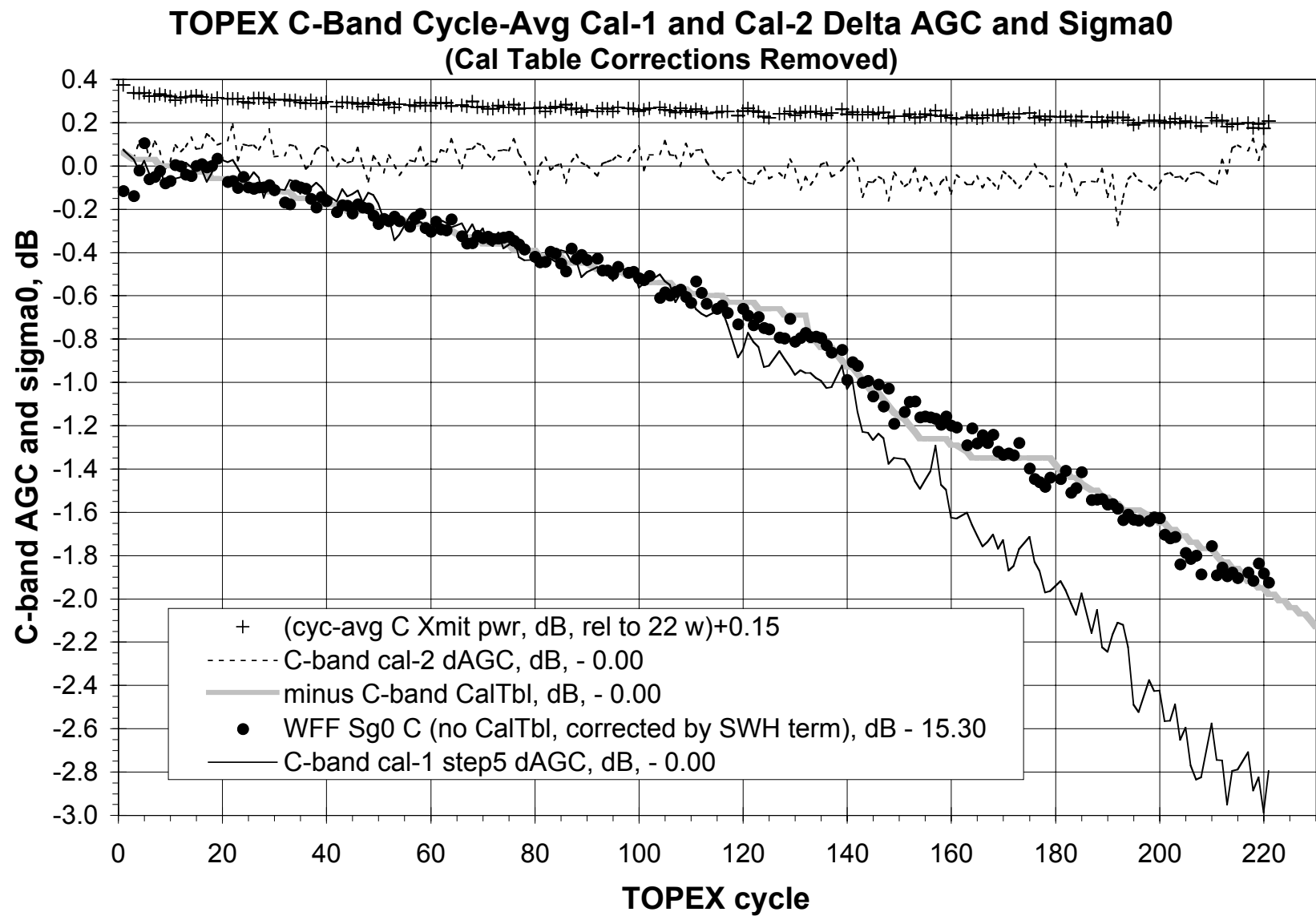


Figure 3

TOPEX Ku-Band Significant Waveheight vs Data Cycle, from WFF GDR Database

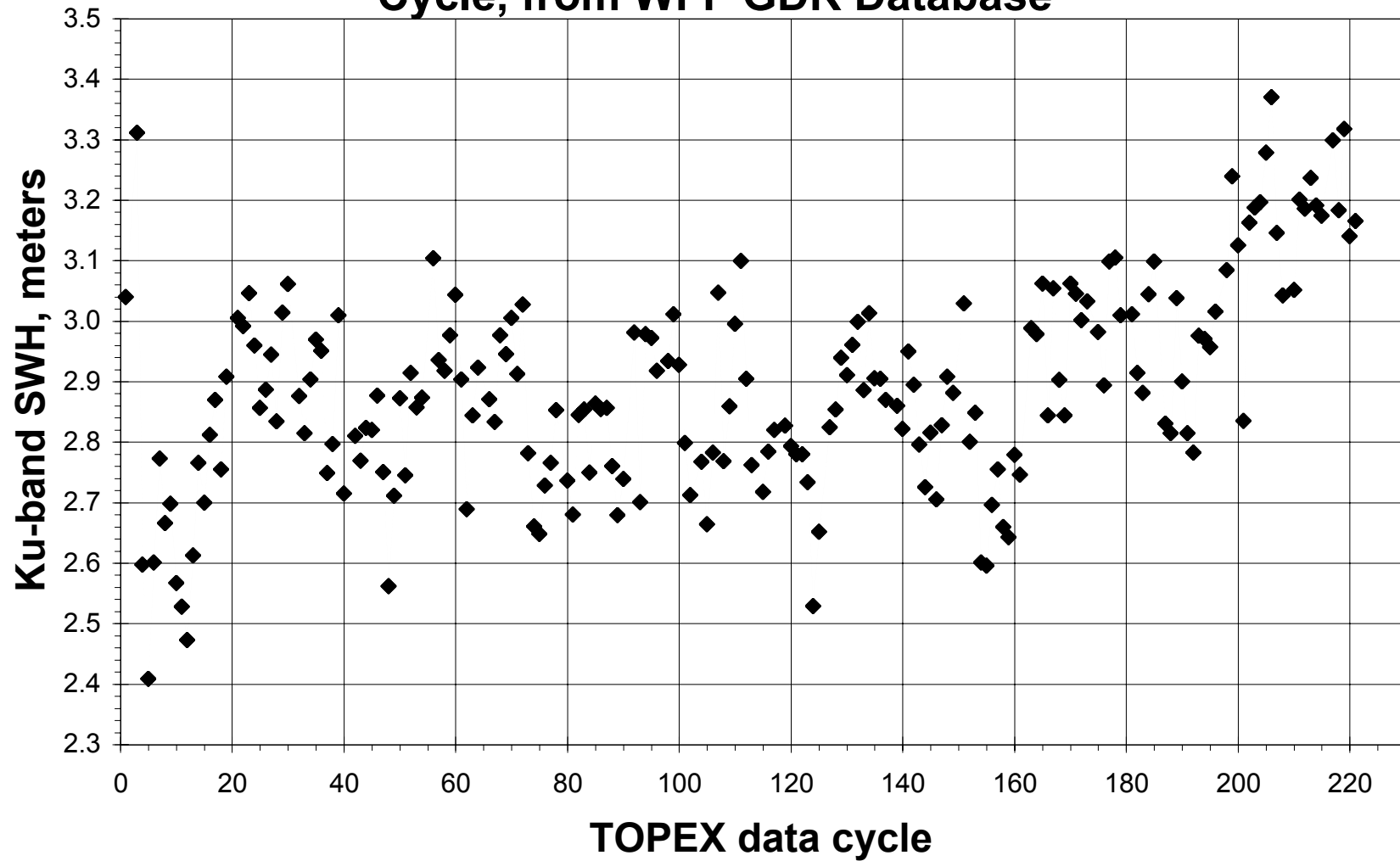


Figure 4

TOPEX Ku Waveform Fit, 5-Second Data Avgs, 1995 Day 058

open circles = corrected telemetry sample in, solid line = waveform fit

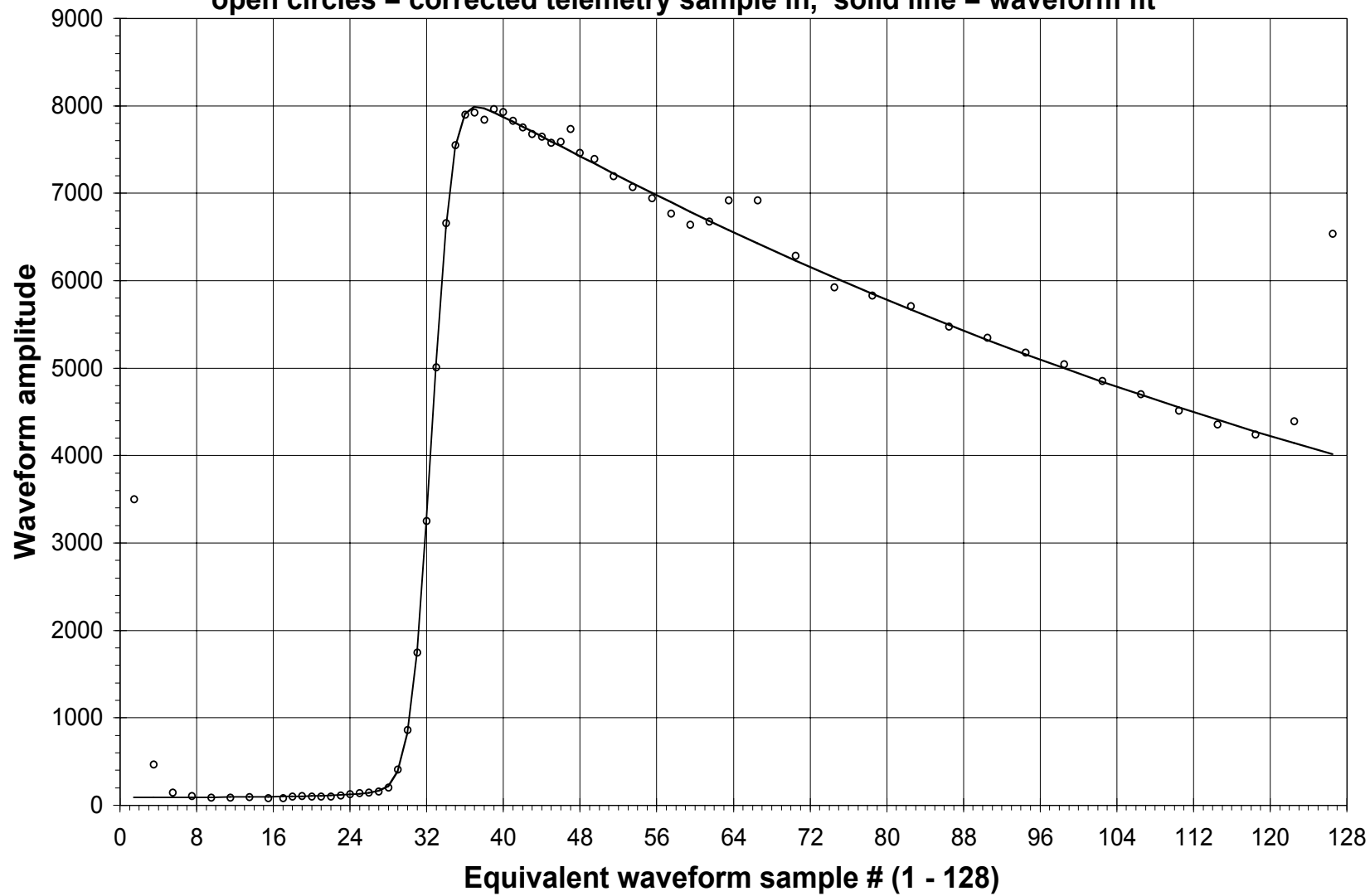


Figure 5

TOPEX Ku Waveform Fit, 5-Second Data Avgs, 1998 Day 176

open circles = corrected telemetry sample in, solid line = waveform fit

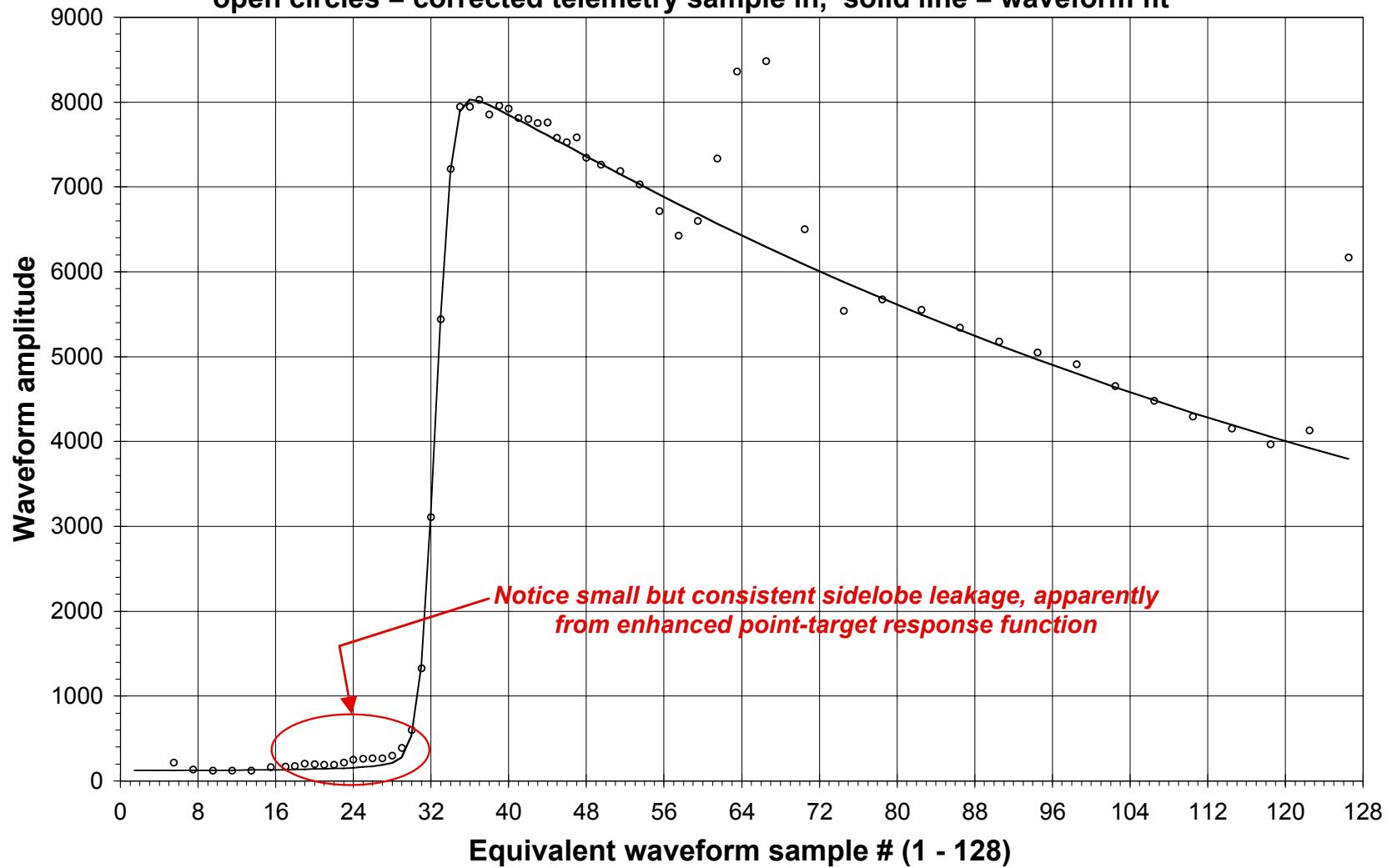


Figure 6

Ku-Band 1998d251 & 1991d155 Cal Sweep, TLM Gates 40, 44, 48

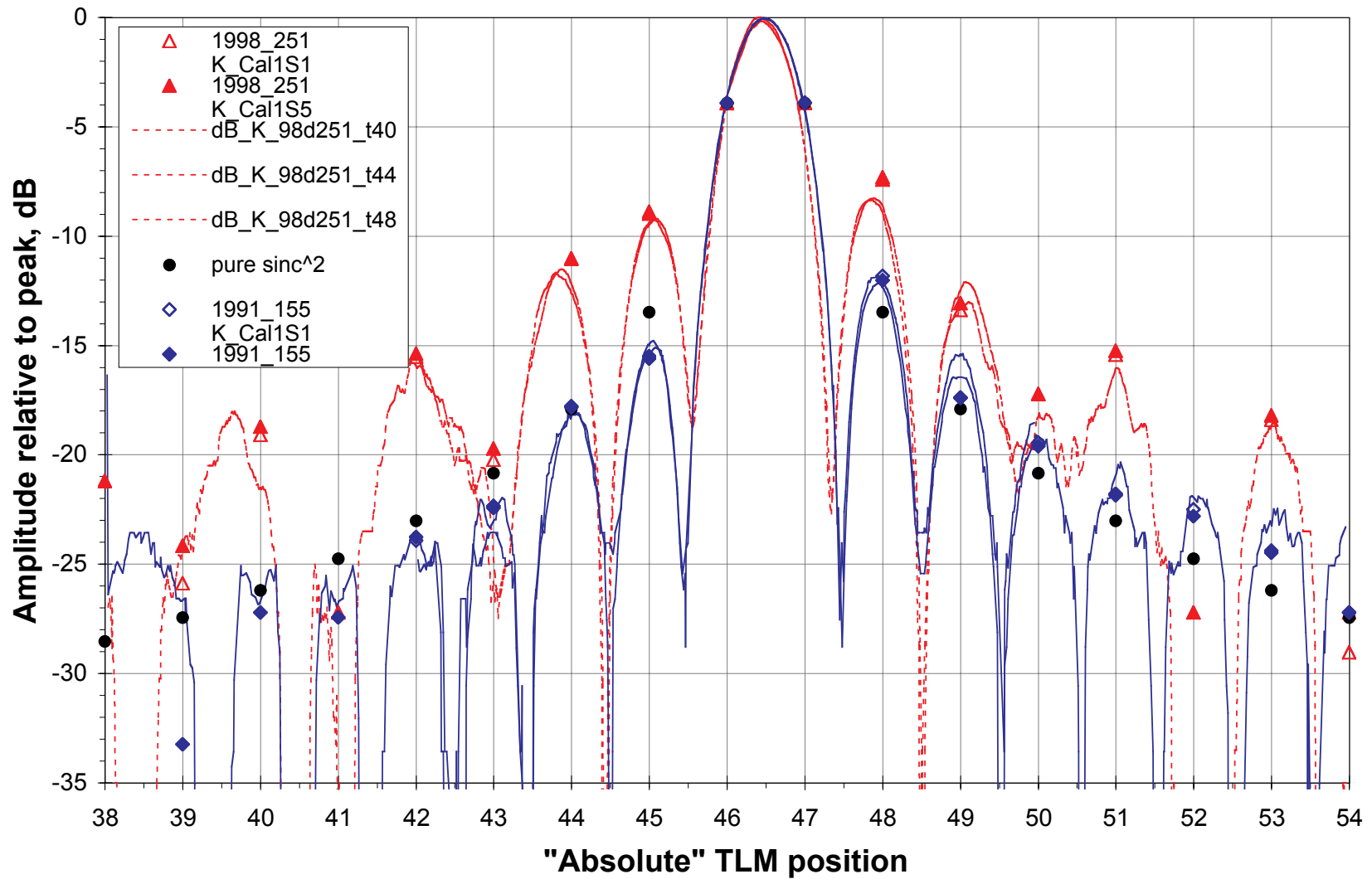


Figure 7

TOPEX Ku- and C-Band Model Point Target Response

from Cal 1 waveforms plus 2 CalSweep tests (1991 & 1998)

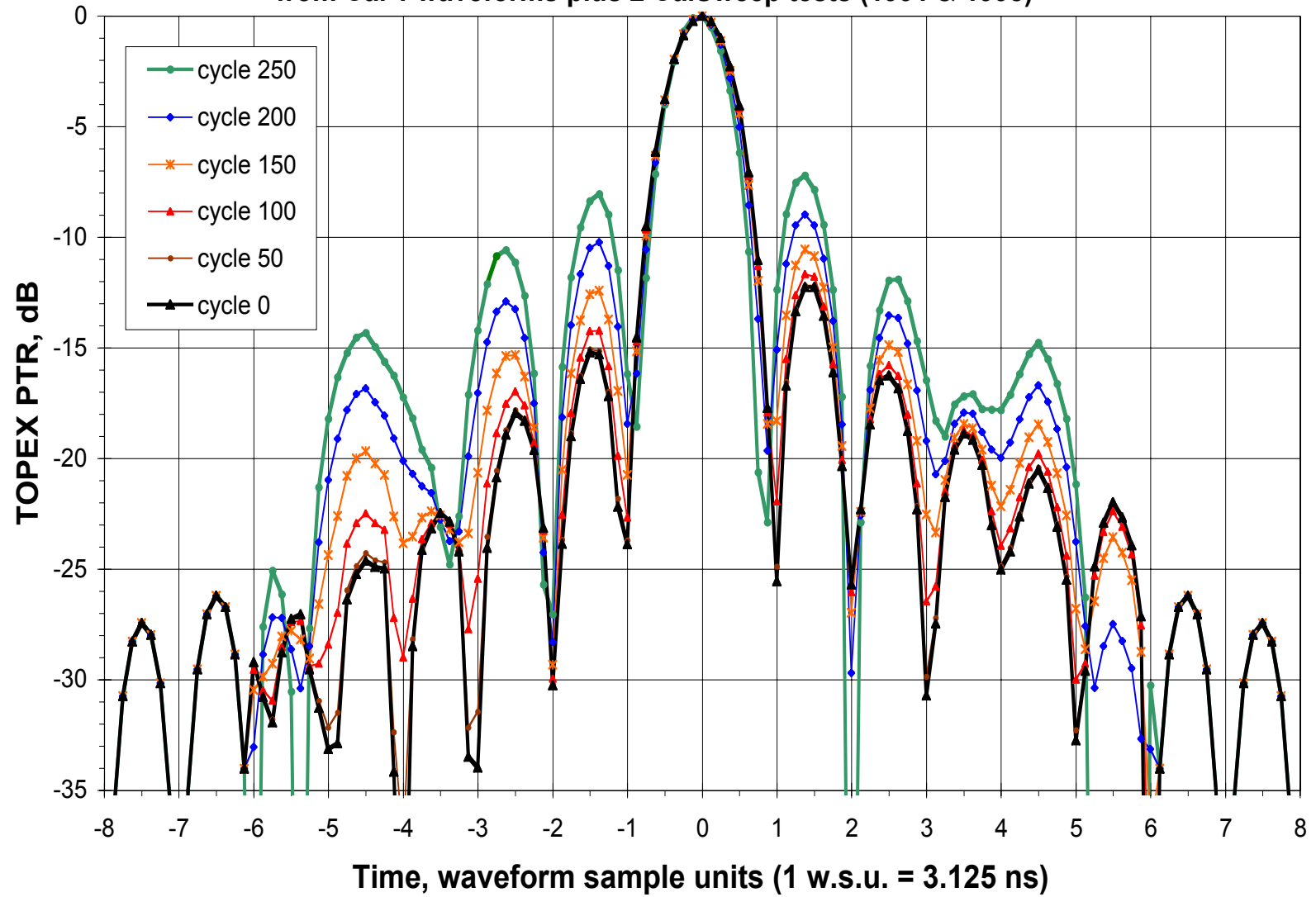


Figure 8

TOPEX Ku-Band Additive SWH Correction Needed

using cycle-dependent PTR model of November 1998

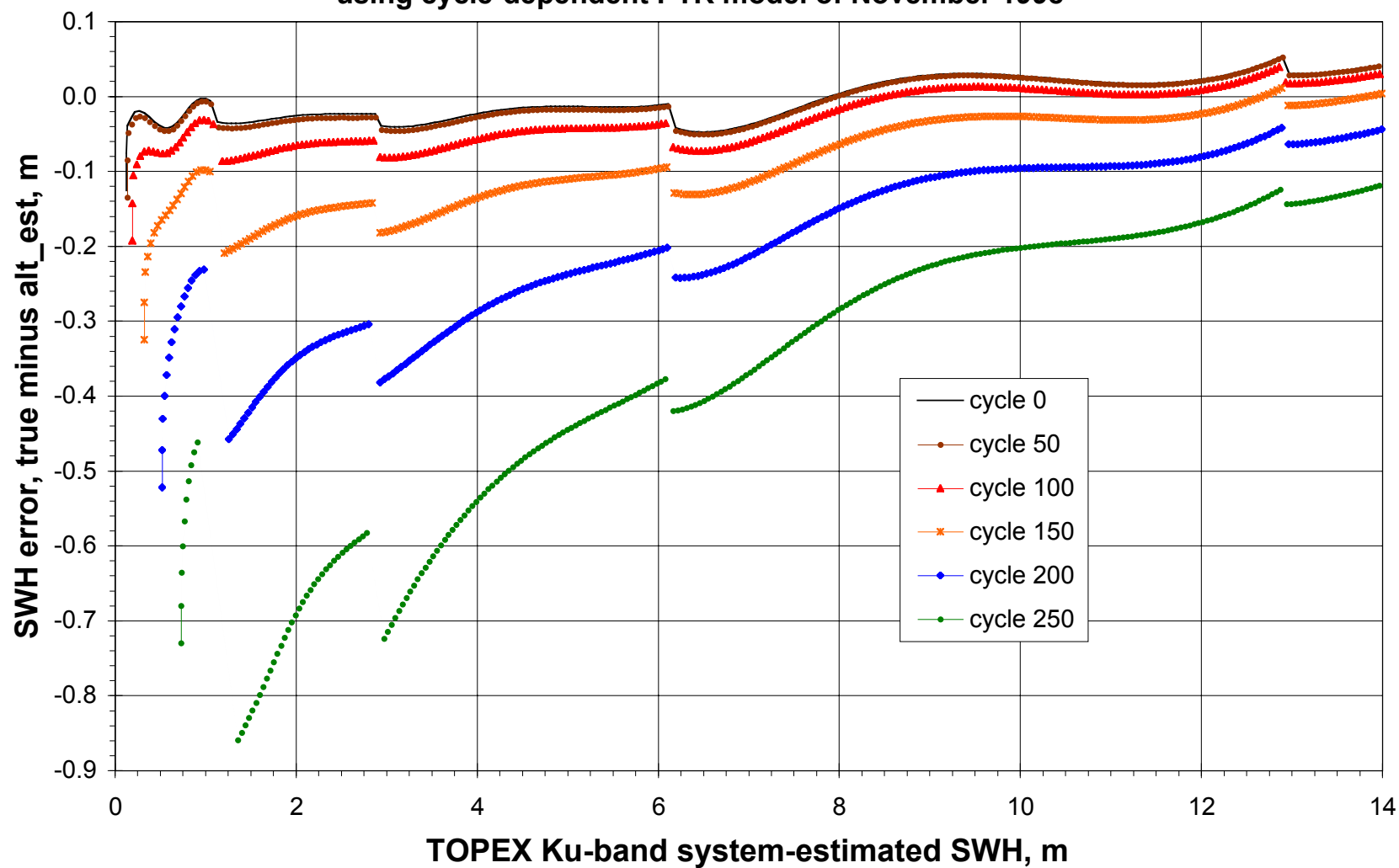


Figure 9

TOPEX Ku-band Additive Range Correction Needed Relative to Cycle 0 for PTR Shape Change Alone

using cycle-dependent PTR model

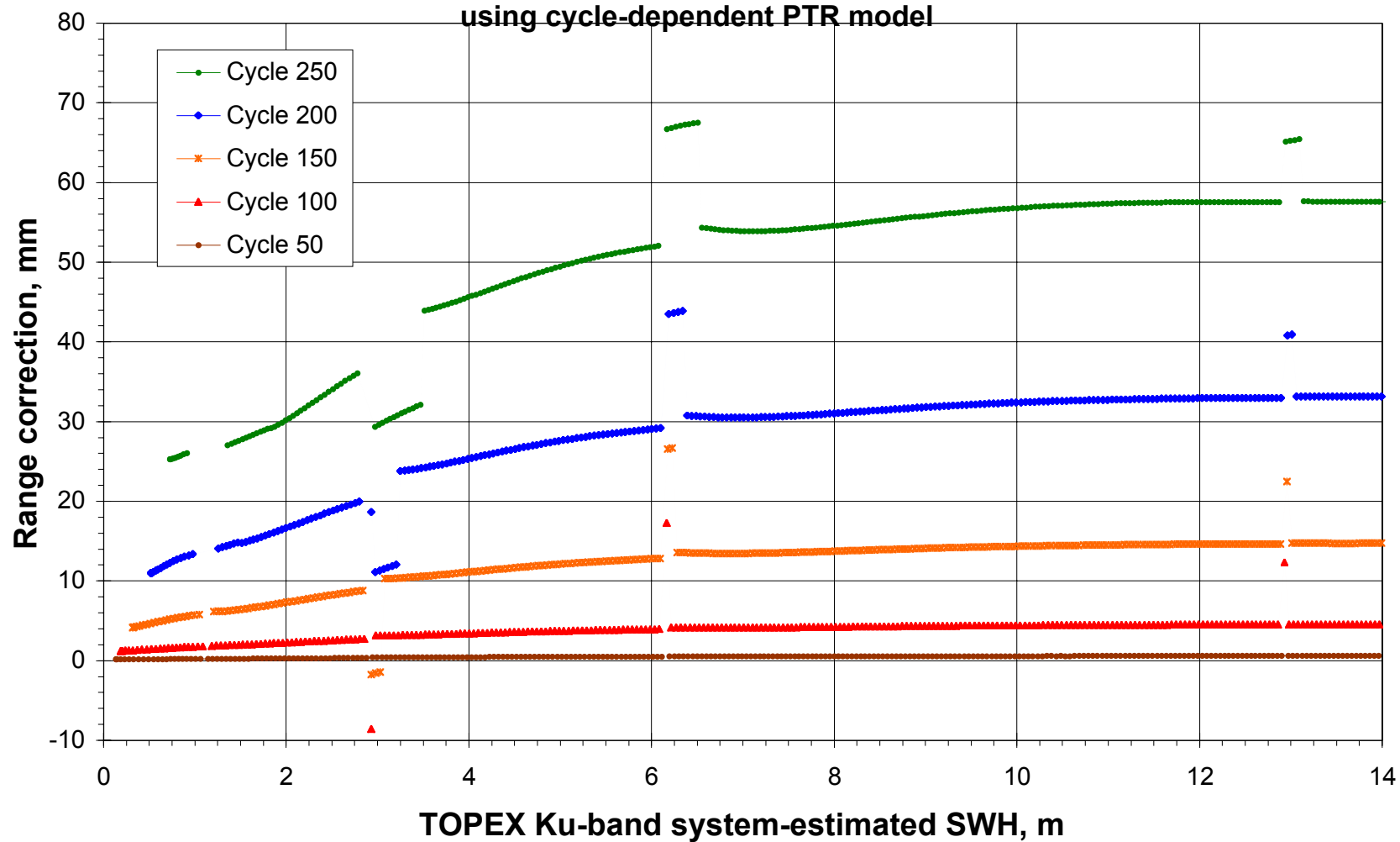


Figure 10

TOPEX Ku-band Additive Range Correction Needed Relative to Cycle 0 for EM Bias Change from SWH Error

using cycle-dependent PTR model and empirical sigma0 vs. SWH curve

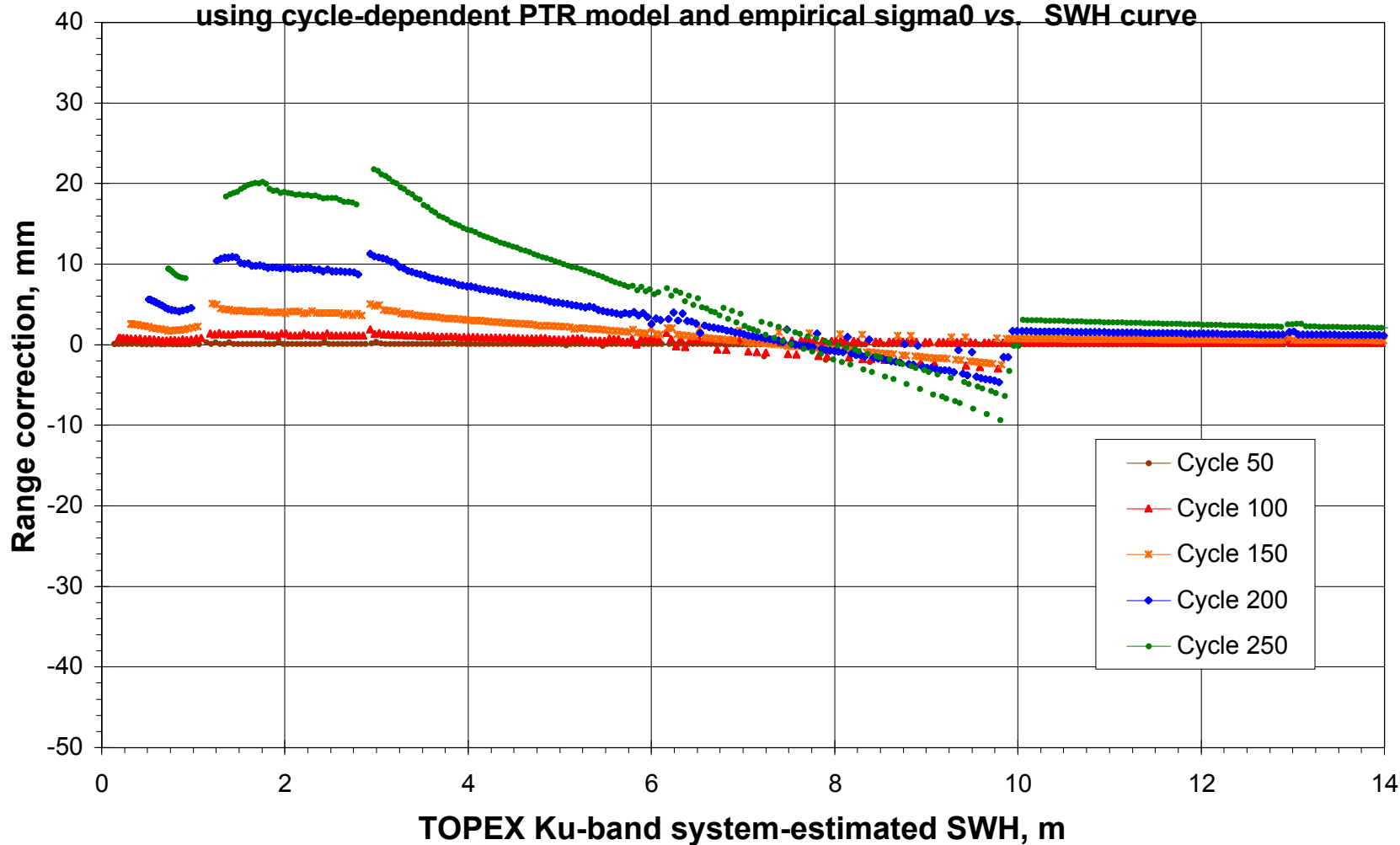


Figure 11

TOPEX Ku-band Additive Range Correction Needed Relative to Cycle 0 for Both PTR Shape Change and EM Bias Change

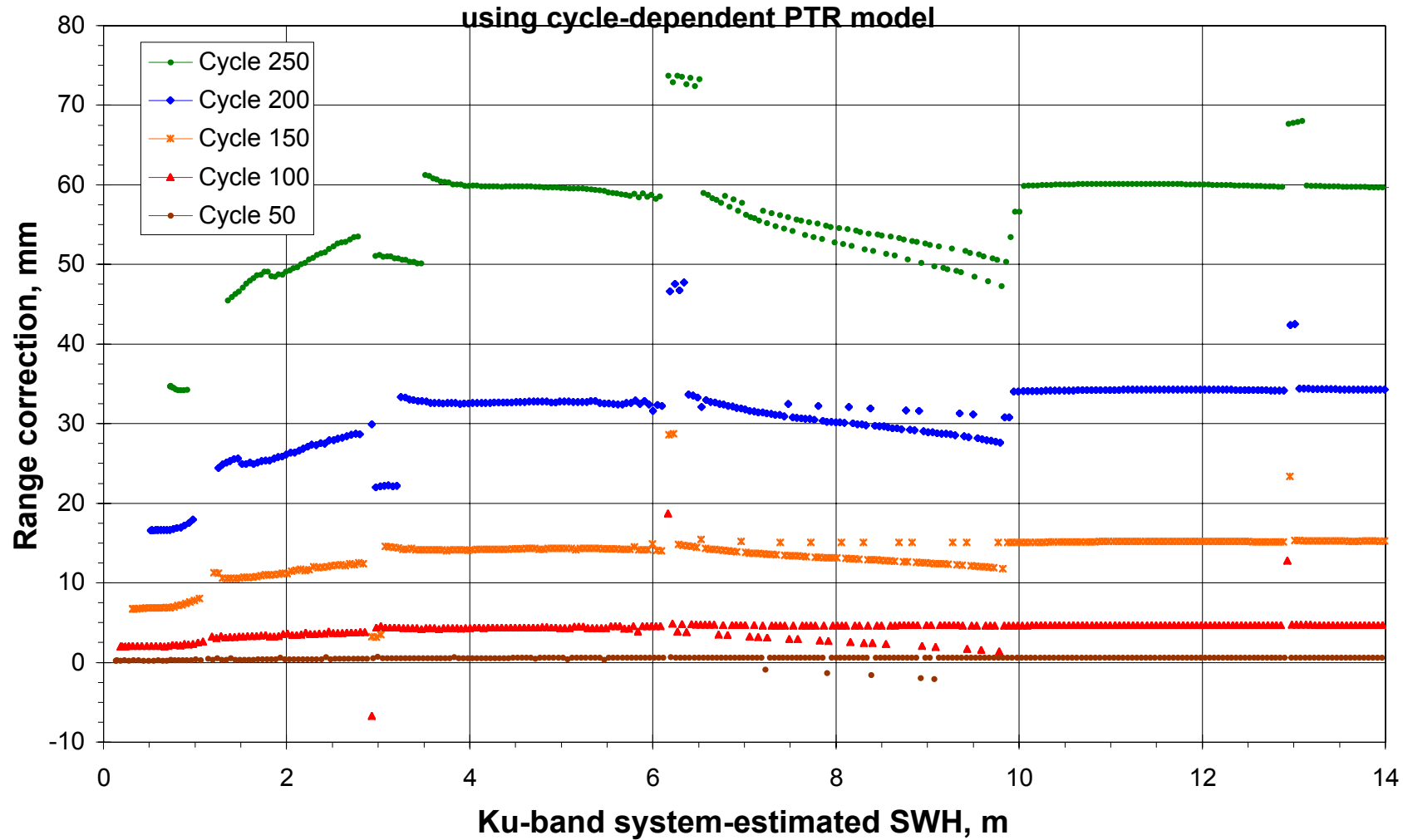


Figure 12

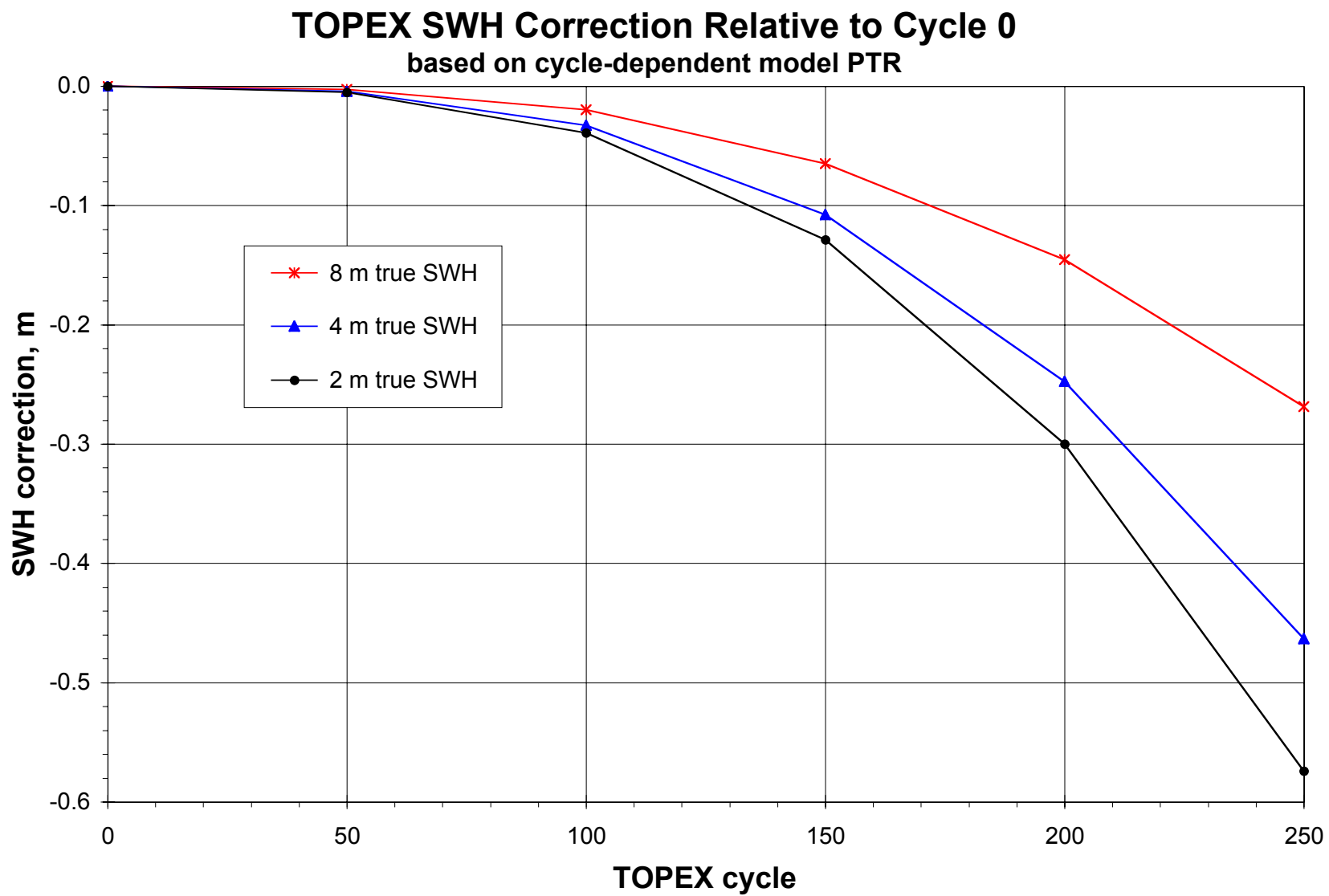


Figure 13

TOPEX Ku-Band Range Correction Relative to Cycle 0, for Both PTR Shape and EM Bias Error from SWH Error

based on cycle-dependent model PTR

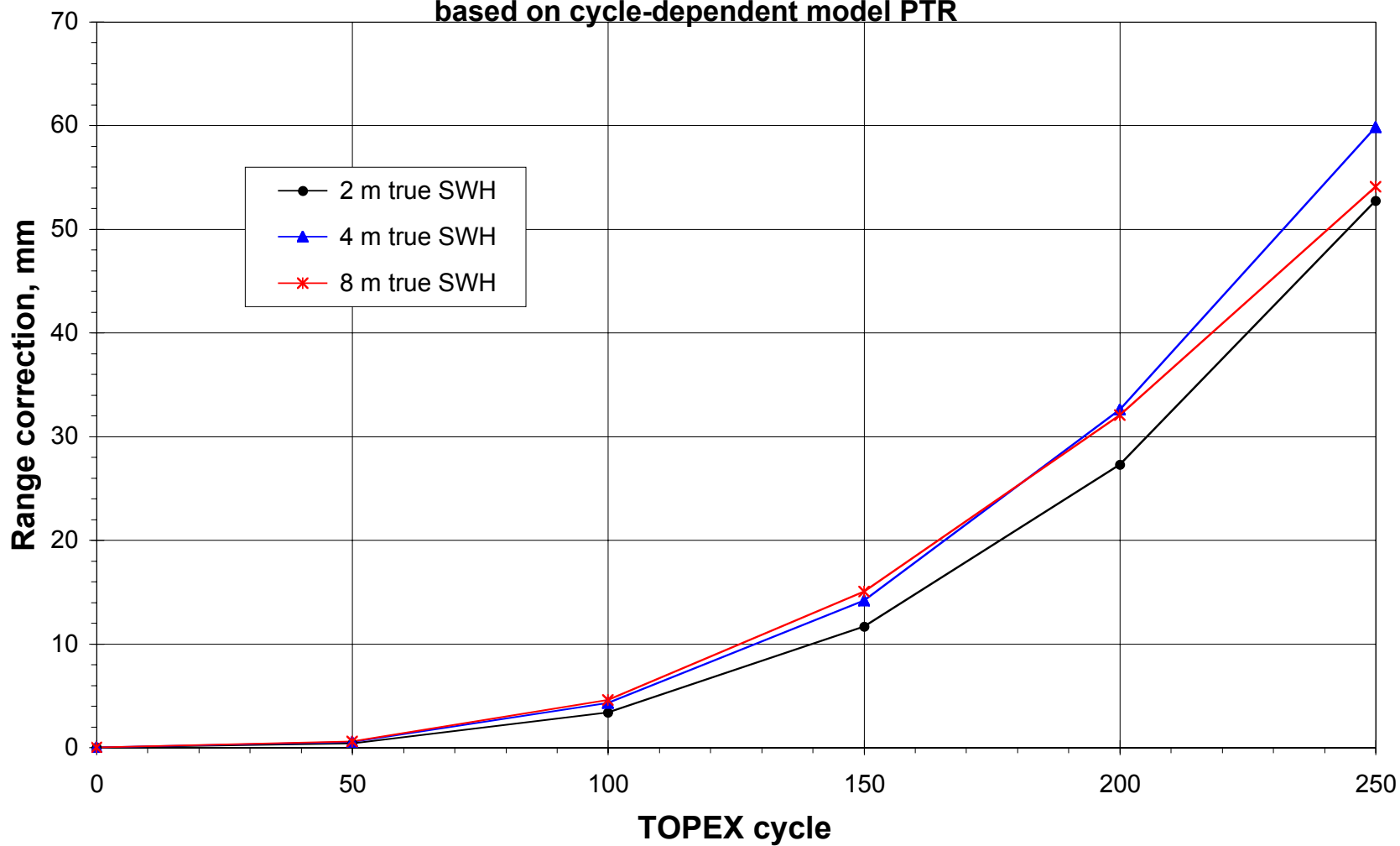


Figure 14

Additional Comments and Conclusions

- The C-band Cal Sweep PTR is almost the same as the Ku-band PTR, so the same cycle-dependent model PTR is now being used for both the Ku-Band and the C-band TOPEX altimeter simulations.
- Only Ku-band simulation results were shown here but C-band simulations, using the cycle-dependent model PTR, produce very similar results. Consequently the ionosphere-corrected range estimates will have about the same characteristics as the Ku-band-only ranges shown here.
- A preliminary version of this work was presented at the TOPEX Science Working Team Meeting, Keystone, Colorado, October 13-15, 1998. The work now being presented is a complete replacement of the earlier work, using the cycle-dependent PTR given above. The range errors now predicted are considerably larger (at least a factor of 4) and in some cases have signs opposite to the earlier results. This indicates the critical importance of the details of the actual system PTR. The PTR is difficult to measure precisely for the TOPEX system on orbit, and even the detailed Cal Sweep provides only a partial look at the actual PTR.
- Since several centimeter range errors are predicted for cycles greater than 200 (TOPEX is in cycle 229 during the Fall 1998 AGU Meeting), these effects should begin showing up in global TOPEX data analyses by various science investigators. We would be very interested in hearing of any such observations.
- The TOPEX altimeter is a redundant system having both an A and a B side. Both sides were fully tested prior to launch, but only Side A has been operated since launch. Plans are now being made to turn on Side B, possibly for a full data cycle, to check its operation and characteristics. It is probable that Side B will not have the degraded PTR shape now seen in Side A, since Side B has been unpowered for the past six years. It may prove desirable to switch all TOPEX operations to Side B after its initial verification, rather than to deal with the increasingly large corrections in Side A, but this is a decision for the Science Team after some Side B data have been acquired and analyzed.